Third United Nations International Conference on the Peaceful Uses of Atomic Energy

A/CONF.28/A/860
NORWAY
February 1964
Original: ENGLISH

Confidential until official release during Conference

Abstract

DYNAMICS OF BOILING HEAVY WATER REACTORS BASED ON HBWR RESEARCH PROGRAMME

by

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In the period from 1960 to 1963 extensive reactor statics and dynamics investigations have been conducted at HBWR to develop models describing the behaviour of natural circulation boiling D_2O reactors. The two fuel charges used in these investigations are: a low-power density aluminium clad, natural metallic uranium fuel charge and a high-power density, Zircaloy clad, 1.5% enriched uranium oxide charge.

The necessary equipment and experimental techniques for obtaining reactor transfer functions were developed and successfully employed in the dynamics programme performed with the metallic fuel charge. In this programme the responses in integral parameters such as power, steam flow, pressure and steam and water temperatures were measured during perturbation experiments. The number of parameters entering the dynamics models are, however, so numerous and the measured parameters so few that by empirical adjustment the models could be constrained to reproduce the experimental results over the ranges of test conditions. It was found difficult through this macroscopic approach to develop models that could be confidently extrapolated to other reactor designs.

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x) Paper prepared and presented on behalf of the O.E.C.D. Halden Reactor Project - a joint undertaking of the European Nuclear Energy Agency.

It was early recognized that the direct measurement of the microscopic parameters such as: channel steam void, fuel and channel coolant temperatures, and local coolant velocities, in addition to the integral parameters, was the most promising approach to the development of models that would permit extrapolations. This recognition, together with an absence of proved instruments for such measurements, led to the development of in-core instruments for the dynamic programme with the oxide fuel charge. The in-core instrument development programme is described in another paper to this conference.

To permit simultaneous analysis of the time behaviour of a large number of in-core signals in the dynamic programme with the oxide fuel charge, an extensive system for automatic data reduction was developed. The system employs a two channel transfer function analyser, a special analogue computer for noise correlation studies, high speed visual recording equipment, a 60 amplifier analogue computer for reducing instrument signals to meaningful dynamic parameters before analysis, an analogue-to-digital converter and a small, but fast, digital computer.

From load perturbation experiments carried out with the low power density metallic fuel charge, it was observed that the nuclear power smoothly followed load changes without unpleasant transients which are characteristic for light water boiling reactors with large (negative) void reactivity coefficients. A quite different behaviour was, however, observed with the oxide fuel charge. When the reactor was subjected to an increase in steam load demand with this fuel charge (operating at power levels above 10 MW), a violent nuclear power transient was observed. This effect turned out to be due to moderator flashing as a result of the decrease in vessel pressure accompanying the increase in steam load demand. A long period instability was actually observed at power levels above 15 MW. From an analysis of this instability, it could be concluded that (1) the flashing instability is of a frequency low enough to be controlled with nuclear feedback control, (2) light water reactors with high coolant void reactivity worth and with down-comer in the reflector where the void reactivity worth is small will

normally not encounter this instability, (3) the instability can be avoided by subcooling of the moderator (e.g. as in the Swedish Marviken reactor).

From the dynamics investigations carried out, it can be concluded that the models previously developed for natural circulation light water boiling reactor stability predictions are not applicable to a natural circulation heavy water boiling reactor. While in the light water boiling reactor dynamic model the entire core is usually considered as a single upcoming boiling channel, with the downcomer in the reflector, there is only a very weak hydraulic coupling between the various channels of a heavy water boiling reactor. This difference between light and heavy water boiling reactors makes it possible to achieve higher coolant power densities stably in D_2O reactors than in H_2O reactors.